

# Techno-economic assessment of telecommunication networks: A COST ANALYSIS OF TELECOMMUNICATION INVESTMENTS

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**Abstract**-The choice of technology implementation on a cost basis depends on many factors including the technical characteristics of the architectures, economic considerations and the actual situation of the operator. Analysing the alternatives for the implementation of telecommunications networks, a thorough examination of the costs and the possible return on investment is necessary. The access network is the most cost sensitive part of the telecom network and in addition the one most closely related to service demand. In the competitive environment, network infrastructure implementations have to be viable in an economic sense. This paper seeks to identify a methodology for an economically viable network implementation introduction, taking into account costing methodologies of such telecom investments.

**Keywords**-Long Run Incremental Cost, Net Present Value, Internal Rate of Return, Busy Hour Erlang

## 1. INTRODUCTION

The rapidly increasing competition in the telecommunications market forces the new operators to minimise costs and maximise revenue streams. The challenge lies in achieving benefit from new and more cost-effective technologies and at the same time being innovative in generating new services that are well-adopted by the customers.

Provisioning of new, advanced services through the introduction of modern technology is commonly expected to be a crucial prerequisite as the operators position themselves for the future service battle.

This project focuses on the design and development of a software tool for the evaluation of telecommunication investments related with establishing service platforms based on existing telecommunication technology solutions. This tool will make it possible to perform fast financial analyses of possible investment plans, combining database management, OA&M cost calculation and equipment dimensioning in sample areas.

Furthermore, the Project aims at extended horizontal investment and techno-economic analyses and concentrates on quantitative analyses, relying on the establishment and use of a common assessment framework, including common models for costing and market forecasting. The methodologies, including costing principles and data, will constitute important

inputs as the network operator's device and form their respective business cases. A generic framework that matches a broad series of different types of technology solutions will add substantial value and new insight into telecommunication investments.

The focus of this paper with respect to cost modelling is:

- An overview of costing concepts, methodologies and approaches, together with their limits and suitable applications.
- The recommended cost model to be used in this Project and elsewhere in assessing telecommunication network investment projects.
- An illustrative example of Long Run Incremental Cost (LRIC) per minute for a GSM network

### 1.1 Cost modelling

The cost modelling methodology and software module should contain the basic ingredient of the cost evolution of network components as a function of time.

As a result of the deregulation of the telecommunication market, incremental methodologies such as LRIC (long run incremental cost) and TELRIC (total element long run incremental cost) have attracted increasing interest. The incremental cost methodologies are described in more detail in Section 2.3.

#### a) Cost module: input requirements

The cost module must receive inputs of the following categories:

- Technology types
- Service Specific Costs
- Project lifetime

When building a new network or upgrading an existing one, an operator has a set of technologies to choose. The cost structure may vary significantly from one technology to the other in terms of up-front costs, variable cost and maintenance costs. Each technology type has elements that are dedicated as for example modems and shared elements such as base stations and cables.

The technology strategy of an operator is defined by the target network architecture and a set of evolutionary paths. Each evolutionary path is defined by a number of technology upgrades within a given period called the study period or

project lifetime. For long term projects, the lifetime is usually 5-10 years.

For each technology type, the following attributes are necessary input to the cost module:

- The equipment price in a given year
- Price trends
- Operation and Maintenance cost parameters

The cost module need inputs from the market segment, which are:

- Penetrations and thereby the number of customers for each service. This information is necessary for the network dimensioning and therefore costs
- Traffic for each service. Used for network dimensioning
- Administrative costs that are related to the customer base

#### *b) Cost module: output requirements*

The cost module gives a range of outputs necessary for the calculation of product indices such as LCC (life-cycle costs), Net Present Value (NPV) and Internal Rate of Return (IRR).

LCC is defined as sum of discounted investments and running costs. These outputs are:

- Yearly investment for each network element
- Yearly maintenance cost for each network element
- Yearly amount for a each type of operation and administration cost

#### *1.2 Business Plan and Strategic Planning analysis*

The main goal of a Business Plan analysis is to evaluate the economics of a new project or a new business.

The incremental cash flows analysis and the indexes calculations (i.e. Net Present Value) support the decision-making process for an investment project: comparing the results of the Business Plans of different (alternative) projects, the Strategic Decision makers can then choose among them in the right way.

The results of the analyses (incremental cash flows) can be used as inputs to Strategic Planning tools to evaluate the evolution of the Fully Allocated Costing methodology (FAC) costs of the single services. This way the strategic planners can see the effects of the new services / network solutions on the overall company trends of costs and revenues and on the profit and loss accounts of each Business Unit (BU, i.e. aggregation of services).

Through the BU profit and loss accounts it is possible to identify the strategic position of the company (e.g. Margin versus Market Share) and the strength and the weakness of the company for each market segment.

## 2. COSTING METHODOLOGIES

### *2.1 Introduction*

This section will cover the main approaches to costing, trying to trace in a clear way the different standpoints and to provide justification for many statement that often appear contradictory regarding costs.

The problem of obtaining the value of the costs related to a product or cluster of products is not a self-defined one. As one approaches to cost evaluation, confusion may arise in finding for the same item more than one possible cost value.

Since such confusion is very likely to happen, in order to define the cost level in a systematic way, some environmental or framework constraints must be introduced.

When introducing a new investment in the Company, i.e. a new service, in order to fill in the business plan cost section it is necessary to consider only the new added costs due to the new investment. So, if a certain amount of Company's spare capacity is reused, those costs will not be reflected in the cost section of the new investment. The cost in this case is either the *current cost* or the *forward looking cost*, depending on the time horizon and strategic choices of the Company, obtained via a *bottom-up* approach. On the other hand, if a cost-based pricing policy is applied, the cost level to be used for pricing must take into account every cost the new service shares with the existing services. The side effect of incrementing the number of services on the shared platform is, therefore, that every service on the platform takes a smaller portion of the shared costs (economy of scope).

### *2.2 Top-down and bottom-up costing processes*

The process of understanding the way costs are generated in the network structure and consumed by the services delivered it is not trivial and requires a structured approach.

Several different methodologies have been introduced to deal with such task, founded on different cost base, but referring to a small set of approaches to identify the productive process. Mostly used among them are the *Top-down* and *Bottom-up* procedures which provide a reference framework to look at the productive process and discover the cost centres, i.e. where and how costs are generated in the company, therefore allowing to thoroughly treat the cost allocation process.

The concept beneath the top-down and bottom-up approach can be briefly summarised as follows:

The *Top-down* approach starts from the general ledger and splits the costs on the elements which build up the delivered services, according to the model of the services, through cost drivers and without taking into account the amount of service delivered (i.e. the demand).

The application of the *Bottom-up* model, instead, requires to refer to the demand of services as starting point, to adopt an appropriate network to serve the demand (a network model is therefore required, together with the dimensioning rules from

which deriving the network elements), and then it provides service cost aggregating by the costs of network elements used by the service.

Costs of services, in both cases are calculated by adding the cost of the elements used to provide that service. This is an element-based approach, which allows tracing the service into the network in every element that contributes to deliver it.

The recent opening of telecommunication market and the introduction of the transparency criteria in dealing with company's network costs, in order to provide the interconnection tariffs between Operators, have caused the two approaches to be the base criteria to attribute costs to the delivered services.

The cost system should lead to efficiency of operators; the use of the resources should be well identified for setting an efficient charges policy. Network Operators providing telephone services and/or leased lines are required to keep separate accounts for their activities related to interconnection – covering both interconnection services provided internally and those provided to other operators and other activities.

TABLE 1. TOP DOWN VS BOTTOM DOWN APPROACH

	Top Down	Bottom Up
<b>Positives</b>	<ul style="list-style-type: none"> <li>&gt; Based on present real cost</li> <li>&gt; Full allocation of Co's cost</li> <li>&gt; Articulated</li> </ul>	<ul style="list-style-type: none"> <li>&gt; No/few confidentiality issue</li> <li>&gt; Efficiency oriented</li> <li>&gt; Transparency</li> </ul>
<b>Negative</b>	<ul style="list-style-type: none"> <li>&gt; Requires confidential info</li> <li>&gt; Includes some inefficiencies</li> <li>&gt; Company's history oriented</li> </ul>	<ul style="list-style-type: none"> <li>&gt; Poor Modelling of OPEX</li> <li>&gt; Danger of over optimisation</li> </ul>

### 2.3 Incremental costing

In the changing environment of the telecommunication scenario, the need to provide an inviting framework for new investors to enter the field lead to some strict requirements on former incumbent's cost accounting systems. Specifically the Regulators agreed that the price the new entrants would have to pay to use the existing connectivity should have been related only to those additional costs originated by the additional demand.

Founded on the above criteria, the principles of efficiency and incremental cost have been merged and a number of methodologies have been created.

- **Short-Run Marginal Cost (SRMC):** The cost of providing additional demand over a short period of time that does not require additional amounts of capacity. It includes direct variable costs only. SRMC could be used only for very short-term business decisions, or for very narrowly defined business objectives.
- **Long Run Incremental Cost (LRIC):** The cost of providing a large number of additional units of a service, over a period of time in which additional capacity will be needed. LRIC can be used for most business decisions, which concern existing services.
- **Total Service Long Run Incremental Cost (TSLRIC):** The cost of providing an entire service (total demand), as compared to not providing the service at all (zero

demand). It includes direct fixed costs, which will not be incurred if the service is not offered, in addition to direct variable and capacity costs. TSLRIC can be used for most business decisions, which concern entirely new services or business ventures.

- **Total Element Long Run Incremental Cost (TELRIK):** It constitutes an evolution of the previous one, defined by the U.S. Federal Commission (FCC) as the TSLRIC of unbundled network elements.

In the following table, the incremental costing are summarised and compared:

TABLE 2. COMPARISON OF INCREMENTAL COSTING APPROACH

	SRMC	LRIC	TSLRIC	TELRIK
<i>Direct Variable Costs</i>	✓	✓	✓	✓
<i>Capacity Costs</i>		✓	✓	✓
<i>Direct Fixed</i>			✓	✓
<i>Shared Costs</i>				✓

#### 2.3.1 LRIC

The name LRIC itself summarises the fundamentals of the methodology:

**Log Run:** stands for the time horizon taken into account in evaluating the Company's costs. It indicates that the costs obtained through this approach are all considered as variable costs, due to the fact that in the long run no cost can be supposed as fixed. The reason for this choice is that of the maximum efficiency, given that in the long run the present infrastructure, eventually affected by the previous history, will migrate to the most efficient one.

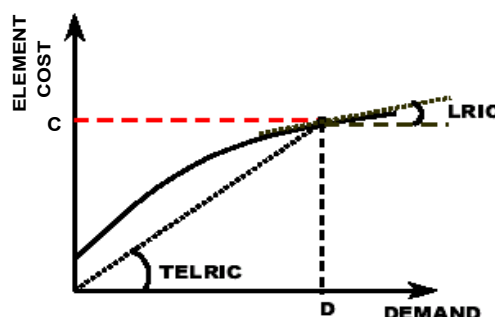
**Incremental Cost:** it complies with the need to determine the cost relative and generated by the finite increment in service demand.

Given that the LRIC should reflect the most efficient productive infrastructure, the productive process itself cannot take into account the history of the company, but it should be demand oriented and describe in a clear manner the cost centres that contribute to service cost.

The Bottom-up methodology is naturally designated to analyse the productive process, thus deriving the network elements costs.

The LRIC procedure provides the incremental cost of assets for a given level of production, i.e. it tells how much would cost to the Company to produce a delta output with respect to the actual output produced.

FIGURE 1. COMPARISON BETWEEN LRIC AND TELRIC.



In Figure 1 there is a graphical representation of the meaning of LRIC compared with the TELRIC. The first one, in fact, takes into account only those costs related to the increment of demand, given the present level. The latter, instead, assumes that in order to provide the most efficient network and to serve a certain level of demand it must completely re-installed, thus the fixed costs are taken into account.

### 2.3.2 Steps to follow to determine costs

1. **Demand:** First of all it is necessary to define the demand for the service to be provided. It is defined in terms of customers, Erlang of traffic, penetration and so on, depending on the nature of the service. These inputs need to be sufficient to feed the dimensioning process that follows.
2. **Dimensioning:** Once the inputs are available, a dimensioning process is activated to provide infrastructure needs to satisfy the demand. This step is performed through network planning rules, whose choice relies on the Operator needs and strategies. At the end of the dimensioning process, components have been calculated and they are reasonably a large amount of different items, cooperating to perform specific functionalities.
3. **Costs:** Every component's cost is evaluated through the price list. In this way total investment for the infrastructure is derived.
4. **Depreciation:** A pay-off policy is applied to obtain the annual cost per component.
5. **Functional Elements:** Components are then grouped by the functionality they perform into Elements, i.e. access, transmission.
6. Summing up the annual cost for the components of every element the annual cost of the element is obtained.
7. **Demand-related cost:** To relate the element cost to the demand originating it, a driver is applied. This is done referring to the service model which is obtained both from the engineering dimensioning process and by analysing the way the resources are used, and gives indication of which functional elements come into play to provide a service.
8. Service cost is then obtained by summing up the elements constituting it.

### 2.3.3 Using LRIC

After the dimensioning process and the cost assignment to the equipment, the element named "trunk" has been defined, derived by aggregation of two different components (for example optical fibre and manpower to connect it to the transmission equipment). Assume that the annual cost of the components sum up to  $C$  Rands. At this stage steps from 1 to 6 of the previous paragraph have been completed. These are in fact the most straightforward and, beside the difficulties related to the dimensioning process or the estimation of demand, they are in principle quite simple.

The task becomes challenging when it comes to identifying the driver to determine the cost/demand ratio. Dimensioning of transmission capacity is done starting from the Erlang

traffic in peak hour to be supported, expressed in Erlang in Busy Hour, which constitutes to the demand. The 'demand in Erlang' is therefore the driver for trunk consumption, and the cost for the element "trunk", relative to busy hour traffic, is then obtained dividing the annual cost of the element by such driver:

$$\text{Annual cost of "trunk" per Erlang in busy hour} = C / (\text{demand in Erlang})$$

At this stage, the annual cost of the element has been distributed on the peak-hour traffic. This value evidently does not consider the fact that the trunk 'works' not only during the peak-hour, but during the whole year. This is obviously not the incremental cost of the element since the two quantities are referred to different time scales ('annual cost' and 'hour traffic').

It is then necessary to use a driver on a yearly time scale, thus distributing element cost evenly on the real demand (traffic served during the whole year), and not only on the traffic of the busy hour. To do so there may be found different criteria, such as dividing the trunk annual cost by the average annual traffic on the trunk, or introducing a coefficient to take into account the ratio between the average daily Busy Hour traffic and the traffic of the whole year.

This quantity represents the unit of cost for the unit of demand to be satisfied.

As shown above, choice of the driver is in principle immediate, since it corresponds to the demand originating the dimensioning of the components, but it has to be carefully considered. In Table 3 some examples of drivers are shown.

TABLE 3. DRIVERS FOR LRIC

Element	Driver	Unit
Access	No. of Subs	Number
Link	Traffic	Erlang
Traffic Sensitive	Circuits	Number
Distance sensitive	Circuits & Length	No. & km

This methodology requires setting up a dimensioning process to come to a correct cost accounting system. This procedure ensures tracing every step for cost allocation and provides costs on different aggregation basis: components, elements, service annual cost, service with respect to demand.

## 3. BOTTOM-UP MODEL

### 3.1 Costing Steps

The first step is the definition of the nature and the extent of all services offered. These will be provision of subscriber lines, switching and transmission and, where appropriate leased lines. The quantity to be provided is derived from the number of lines and the telephone calls demand.

The second step should identify the investment volume required to build a local network infrastructure capable of satisfying demand, having account of technical constraints and efficient service provision. The investment must be valued at current prices for guarantying efficient use of resources. While

regarding demand, two demand parameters must be considered for the model:

- Demand of subscriber lines
- Busy hour traffic demand

The investment cost should be converted into annualised costs, having account of depreciation, return on capital and current operating costs. This is possible by using annualisation factors. In order to determine the annual costs of providing the networks elements, the cost of capital should be established. First the productive capital is valued at replacement cost and secondly depreciation periods and methods are specified, and finally expect return on capital must be established.

Asset-Related Operating Costs are costs arising from day-to-day operation of the telecommunications network (OAM costs). They must be added to the direct capital costs of the stock of assets.

The long run incremental costs of the elements of the switched network are the annual costs of providing peak load capacity, i.e busy hour Erlangs. This cost is converted into cost per minute, based on the convention that the costs of the network element are spread evenly over total output. Keeping capacity available for peak loads causes costs of conveyance (cost arising from the use of network elements). The peak load capacity costs are then divided by per year demand, expressed in terms of call minutes. Taking into account usage factors, costs per unit of output are established for each traffic-sensitive network element.

The costs of interconnection result from the total costs of network components used. This requires identifying for each element the usage factors that should explain how many units of output from a given element are used in the production of one unit of interconnection (typically minutes).

TABLE 4. LRIC CALCULATION STEPS: BOTTOM-UP

Step	Bottom-up Approach
1	Establish network design
2	Identify and determine capital cost of network elements
3	Calculate operating expenditure
4	Combine capital and operating costs into annual cost per network element
5	Divide network elements by minutes of traffic
6	Bundle network element minutes to calculate LRIC of each service
7	Mark-up LRIC to set charges
8	De-average charges

### 3.2 Costs per Unit of Demand

The model calculations made so far form the basis for determining the long run incremental costs of the separate network elements and of access services at local network level. In line with the procedures, the costs are annual costs of the entire infrastructure of the local network studied. Where expected traffic demand plays a role in determining the investment volume, these costs are also seen as costs incurred for providing capacity to cover busy hour demand. Hence establishing the costs of an average call minute presupposes determination of annual demand.

### 4. ILLUSTRATIVE EXAMPLE OF LRIC PER MIN FOR GSM

An appropriate costing exercise would entail a careful examination of the topology of the network, the geographic and demographic features of the country under consideration and, last but not least, an accurate analysis of the demand side of the market. A bottom-up model would need to identify the total amount of equipment needed to serve demand.

As discussed in Section 2, the cost drivers of traffic and coverage area are cost drivers that affect most of the costs of a mobile network. Potentially important cost categories include the cells (these include tower, antennae, and the site), TRXs, backhaul, BSCs, transmission in the backbone network, MSCs, VLRs, HLR, and network management equipment. There are both capital and operational costs that need to be calculated.

The approach developed is a “micro” approach that looks at various network elements in isolation. The annual cost of each element is divided by the number of minutes the average element is assumed to serve during a year. Annual minutes are obtained through the conversion of Busy Hour Erlang (this is a measure of Busy Hour traffic, which network elements are usually dimensioned to carry) into annual traffic.

The approach seeks to identify a cost per minute for each of the major network elements. Summing these gives an average cost per minute. However, this does *not* provide the cost of a minute of origination/termination services. To get cost estimates for services, information would be needed on how different services use on average different network elements.

Among the different cost categories, it is the per minute cost of cells that is most sensitive to assumptions about population density. Given the overall impact of these costs on total costs, we distinguish, therefore, between two scenarios and estimate per minute costs of the following two different networks.

- Rural network.* Traffic over the network is such that the cost driver of each cell turns out to be coverage.
- Urban network.* Traffic over the network is such that the cost driver of each cell turns out to be capacity.

The approach requires assumptions about the cost of the various network elements and about the annual number of call minutes that any element might serve under the two different scenarios.

Table 5. gives the relevant technical assumptions made for each network element under the two different scenarios.

#### 4.1 Deriving Annual Call Minutes

To estimate the number of call minutes that an element serves in a year, we have made assumptions about the number of BHE the same element serves. The number of BHEs an element serves is then converted into the total number of call minutes carried through appropriate assumptions.

The final results are quite sensitive to the assumptions made about the relationship between annual call minutes and BHEs.

The conversion factor is here defined through the following equation:

TABLE 5. TECHNICAL ASSUMPTIONS FOR TWO SCENARIOS

<i>Network Elements</i>	<i>Rural</i>	<i>Urban</i>
No of sectors in cells	1	3
Average capacity per cell (BHE)	4	10
Average No. of TRXs per sector	1	3
Average length of backhaul (Kms)	20	20
Average capacity of backhaul (BHE)	4	30
Average capacity of backhaul (Mbit/s)	2	2
No. of TRXs served by the same BSC	80	80
Average length of the BSC – MSC (Kms)	60	60
Average capacity of the BSC – MSC (BHE)	246	320
Average capacity of the BSC – MSC (Mbit/s)	34	34
Average length of the MSC – MSC (Kms)	150	150
Average capacity of the MSC – MSC (BHE)	1,476	1,848
Average capacity of the MSC – MSC (Mbit/s)	155	155 + 34
Annual minutes served by each MSC (min)	1,500	1,500
BHE per MSC port	15	15

*Conversion factor = Annual call minutes / BHE*

For the purposes of this example the conversion factor used is that in the publicly available Analysys model developed for OfTel in 2001. The conversion factor used and the assumptions underlying it are summarised in Table 6.

#### 4.2 Assumptions and Results

TABLE 6. ASSUMPTIONS UNDERLYING BHE FACTOR

<b>Assumptions</b>	
Percentage of daily calls attempted during the Busy Hour	15%
Number of Busy Hour Days in a year	250
Average duration of a call attempt (minutes)	3
Conversion factor (i.e., No of annual call minutes per BHE)	100,000

The following tables summarise the results of the cost assumptions underlying the per minute estimates of the network elements.

Summing the per minute cost charges produces an average per minute cost charge. This would only accord with the per minute cost charge for a particular service if it is assumed that all services make the same use of the different elements.

When valuing the results of this exercise, it is important to bear in mind that the network elements, whose costs have been estimated, do not cover all network costs. All those network components that are in the network to provide functionality to these elements, such as racks for MSCs or power generators placed in the sites, are not included in this estimate.

TABLE 7. PER MINUTE COSTS OF THE NETWORK ELEMENTS – RURAL NETWORK

<b>Equipment</b>	<b>Total Annual Cost (€)</b>	<b>Annual minutes served</b>	<b>Cost per minute (€/100)</b>
1 sector Cell (total)	78,600	400,000	19.65
TRX	9,400	310,000	3.06
Backhaul	12,800	400,000	3.20
BSC	376,000	24,620,000	1.53
BSC – MSC	52,400	24,620,000	0.21
MSC (Total)	1,333,000	1,500,000,000	0.09
MSC ports	1,800	1,500,000	0.12
MSC – MSC	200,000	147,600,000	0.14
HLR	249,600	1,500,000,000	0.00
Network Manage	9,360,000	1,500,000,000	0.01
<b>Total</b>			<b>28.0</b>

TABLE 8. PER MINUTE COSTS OF THE NETWORK ELEMENTS – URBAN NETWORK

<b>Equipment</b>	<b>Total Annual Cost (€)</b>	<b>Annual minutes served</b>	<b>Cost per minute (€/100)</b>
3 sector Cell (total)	110,000	3,000,000	3.67
TRX	9,400	400,000	2.35
Backhaul	12,800	3,000,000	0.43
BSC	376,000	32,000,000	1.18
BSC – MSC	52,400	32,000,000	0.16
MSC (Total)	1,333,000	1,500,000,000	0.09
MSC ports	1,800	1,500,000	0.12
MSC – MSC	252,400	184,800,000	0.14
HLR	250,000	1,500,000,000	0.00
Network Management	9,360,000	1,500,000,000	0.01
<b>Total</b>			<b>8.1</b>

#### 5. CONCLUSION

In this paper the main emphasis is on the evaluation of telecommunication network investment analysis, and hence investigation of the most relevant costing methods for strategic planning of telecommunication networks.

The top-down model uses a financial approach (starting with the accounts) and the bottom-up models are much closer to the engineering point of view. In any case, it may be said that, in a medium-term, both models should converge to the same results. This will be achieved by using correct cost drivers and dimensioning algorithms.

A regulator generally imposes the use of one of the two approaches (i.e. top-down or bottom-up); then, the PNO should use either approach imposed by the regulator to present the accounting information to be presented to the regulator.

The main results of this work are the following:

- An overview of costing concepts, methodologies and approaches, together with their limits and suitability in different applications; including giving a clear classification of the concepts.
- A recommended bottom-up cost model to be used in the comparative analysis in assessing telecommunication network investment. Methodologies for splitting the costs into several components were described. This includes the modelling of cost per service.

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